

Abstract

Material extrusion additive manufacturing is a widely used process for producing complex parts from thermoplastic polymers. However, the quality of the final product is heavily influenced by the flow behavior of the polymer melt through the hot-end and the nozzle. In order to optimize the extrusion process, reduce defects such as extrusion inconsistencies, and improve the quality and performance of the final product, a comprehensive understanding of the flow behavior is essential.

In this project, the flow behavior of polymer melts in fused filament fabrication 3D printing technology through the extrusion mechanism known as the hot-end will be investigated experimentally. A test setup was built to extrude polymer melts at different melt temperatures while measuring the force exerted using load cell.

The goal is to develop a control system that can optimize the extrusion process and interpret the force data to achieve optimal results. Additionally, a key objective of this study is to conduct a comparative analysis of PLA (Polylactic acid) and TPU (thermoplastic polyurethane) materials, assessing how each responds to varying extrusion conditions. This comparison aims to uncover the distinct properties and behaviors of these polymers, offering valuable insights for their application in 3D printing. The results of this comparison are crucial for understanding material-specific requirements and tailoring the extrusion process accordingly.

Data from the test setup were collected and analyzed using MATLAB. A key challenge encountered was the non-linear behavior of the heater model, which led to the development of the advanced Hammerstein model. However, due to complexities in designing a controller for this model, a PID Controller was employed. Utilizing MATLAB's PID tuner, optimal values for K_p , K_i , and K_d were determined to effectively control the heater.

The study demonstrates that extrusion parameters like speed, temperature, and feeding force critically affect the quality of 3D prints. It thoroughly investigates how these factors interact, enhancing our understanding of their role in 3D printing. This research significantly advances the field by providing deeper insights into material properties and suggesting ways to improve 3D printing techniques, laying groundwork for future advancements